

Completion of Population of and Quality Assurance on the Nuclear Fuel Cycle Options Catalog

Fuel Cycle Research & Development

*Prepared for
U.S. Department of Energy
Fuel Cycle Options Campaign
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SUMMARY

An Evaluation and Screening team supporting the Fuel Cycle Technologies Program Office of the United States Department of Energy, Office of Nuclear Energy is conducting an evaluation and screening of a comprehensive set of fuel cycle options. These options have been assigned to one of 40 evaluation groups, each of which has a representative fuel cycle option [Todosow 2013]. A Fuel Cycle Data Package System Datasheet has been prepared for each representative fuel cycle option to ensure that the technical information used in the evaluation is high-quality and traceable [Kim, et al., 2013].

The information contained in the Fuel Cycle Data Packages has been entered into the Nuclear Fuel Cycle Options Catalog at Sandia National Laboratories so that it is accessible by the evaluation and screening team and other interested parties. In addition, an independent team at Savannah River National Laboratory has verified that the information has been entered into the catalog correctly. This report documents that the 40 representative fuel cycle options have been entered into the Catalog, and that the data entered into the catalog for the 40 representative options has been entered correctly.

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ACRONYMS

FCDP – Fuel Cycle Data Package

FUEL CYCLE OPTIONS CAMPAIGN

COMPLETION OF POPULATION OF AND QUALITY ASSURANCE ON THE NUCLEAR FUEL CYCLE OPTIONS CATALOG

1. INTRODUCTION

An Evaluation and Screening Team supporting the Fuel Cycle Technologies Program Office of the United States Department of Energy, Office of Nuclear Energy is conducting an evaluation and screening of a comprehensive set of fuel cycle options. These options have been assigned to one of 40 evaluation groups, each of which has a representative fuel cycle option [Todosow 2013]. A Fuel Cycle Data Package (FCDP) System Datasheet has been prepared for each representative fuel cycle option to ensure that the technical information used in the evaluation is high-quality and traceable [Kim, et al., 2013].

The information contained in the FCDPs has been entered into the Nuclear Fuel Cycle Options Catalog at Sandia National Laboratories so that it is accessible by the evaluation and screening team and other interested parties. In addition, an independent team at Savannah River National Laboratory has verified that the information has been entered into the catalog correctly. The purpose of this report is to document that the 40 fuel cycle options have been entered into the Catalog, and that the data entered into the catalog for the 40 fuel cycle options has been entered correctly. This report does not describe the capabilities of the Nuclear Fuel Cycle Options Catalog, the nuclear fuel cycle option grouping structure, or other content in the Nuclear Fuel Cycle Options Catalog (either previously entered or planned for inclusion in the future).

Section 2 presents the contents of a FCDP, Section 3 demonstrates example pages of how the FCDP information is reproduced in the catalog, and Section 4 discusses the verification process.

2. CONTENTS OF A FUEL CYCLE DATA PACKAGE

A FCDP is generally about 9 pages long. Table 1 gives the content of each page, and a sample FCDP is provided in Appendix A.

Table 1. Contents of a FCDP

Page Number	Contents
1	Summary Description
2	Material Flow Diagram
3	High-Level Parameter Data for the Nuclear Power Plant/Transmutation System
4	High-Level Parameter Data for the Nuclear Fuel
5	High-Level Parameter Data for Reprocessing/Separations (if used)
6	Fuel Cycle Performance Summary – Evaluation Criteria and Metrics (not currently used)
7	Mass Flow Data table
8	Transition and Scenario Analysis Description
9	References

The Summary Description (page 1) includes the name of the option, an identification of the option group it belongs to as defined by Todosow et al. [2013], a summary description of each stage of the fuel cycle option, and a record of who prepared, reviewed, and approved the FCDP. The Material Flow Diagram (page 2) is a pictorial depiction of how various nuclear fuel cycle materials flow through the system, focusing on the energy-generating part of the option (fuel, reactor, and reprocessing/separations). The next three pages (pages 3-5) provide high-level parameters for the transmutation system(s) (e.g., reactor(s)), fuel(s), and reprocessing/separations(s) processes, respectively. These are option-specific parameters that are used to calculate various measures of the option's performance that are, in turn, used to evaluate the option against established criteria and metrics.

The Mass Flow Data table (page 7) shows the masses of nuclear materials (e.g., natural uranium, thorium, U233, plutonium, minor actinides, and fission products) in each stage of the option, and shows whether the material is consumed or produced in each stage. The Transition and Scenario Analysis Description page (page 8) is intended to provide any available transition or scenario fuel cycle information. The fuel cycles being evaluated are assumed to be in equilibrium (e.g., not in transition). References that support the information provided in the FCDP are given on page 9.

In addition to the information in a FCDP, the isotopic composition of the various fuels (charged and discharged from each reactor for each stage) accompanies each FCDP and is captured in the Nuclear Fuel Cycle Options Catalog.

The information in each FCDP is captured in the Nuclear Fuel Cycle Options Catalog and presented to the user in a different format, as discussed in Section 3.

3. FCDP INFORMATION IN THE FUEL CYCLE OPTIONS CATALOG

The information in each FCDP is input into the Fuel Cycle Option Catalog database in such a way that it can be retrieved as desired in the form of a database report. An example of how the Summary Description of each option is provided in the Fuel Cycle Option Detail report is shown in Figure 1 and Figure 2, which show the top half and the bottom half of the Fuel Cycle Option Detail report, respectively. In addition to the Summary Description of the fuel cycle option that came directly from the FCDP, the Fuel Cycle Option Detail report also provides an overview of the technologies used in the option.

The Material Flow Diagram in the FCDP for each option has been turned into an "Interactive Option Flow Diagram," an example of which is shown in Figure 3. When in the catalog, clicking on one of the yellow objects in the diagram or words in the diagram (e.g., LEU,DF) will open a database report giving all the information available regarding that item.

The high-level parameters for the transmutation system(s), the fuel(s), and the reprocessing/separations system(s) (if used) are also given in database reports, as shown in Figure 4, Figure 5, and Figure 6. These database reports can be accessed either by clicking on the appropriate object in the Interactive Option Flow Diagram (Figure 2), or by clicking on the "Option Parameters" associated with the desired technology in the Fuel Cycle Option Detail report (Figure 1).

The Mass Flow Data table can be accessed from the Fuel Cycle Option Detail report (Figure 1) by clicking on "Option Mass Flow Data File" in the "View Additional Fuel Cycle Option Information" box. An example Mass Flow Data Table is shown in Figure 7. In the catalog, the mass flow data is captured as an entire table, not as discrete numbers.

The Transition and Scenario Analysis page on the FCDPs is rarely filled out. If it is, it can be accessed by clicking on "Additional Information" in the "View Additional Fuel Cycle Option Information" box in the Fuel Cycle Option Detail report. Note that the example fuel cycle option in Figure 1 does not have any

additional information, so the term “Additional Information” does not appear in the “View Additional Fuel Cycle Option Information” box in Figure 1.

The references in the FCDP can be access by clicking on “Option References” in the “View Additional Fuel Cycle Option Information” box in the Fuel Cycle Option Detail report (see Figure 1). An example reference database report is shown in Figure 8.

Fuel Cycle Option Detail

Number of Stages	1	Review Disposition	Accepted	Review Author	A. O. Delley (SRNL)	Status	Active	Screening Disposition	Not Yet Screened							
High Level Objectives	1) Produce electricity 2) Can utilize existing thermal reactor infrastructure			Recycle Strategy	No Recycle	Road Map Strategy	Once Through									
View Additional Fuel Cycle Option Information <table border="1"> <tr> <td>Interactive Option Flow Diagram</td> <td>Option Mass Flow Data File</td> <td>Option References</td> <td>Option Metrics</td> </tr> <tr> <td>Option Data Package File</td> <td>Option Isotopic Data File</td> <td colspan="2">Option Predecessor/Successors</td> </tr> </table>					Interactive Option Flow Diagram	Option Mass Flow Data File	Option References	Option Metrics	Option Data Package File	Option Isotopic Data File	Option Predecessor/Successors		Revision Remarks	Incorporation of external review comments		
Interactive Option Flow Diagram	Option Mass Flow Data File	Option References	Option Metrics													
Option Data Package File	Option Isotopic Data File	Option Predecessor/Successors														
Data Pkg	EG01/OT01A	Data Pkg Revision	Rev 1.0	Option Group	(EG01) OT01A-C-T-U-Y											
Is Representative of Group	Yes	Source	DOE													
Stage Nbr	Stage Description		Technology Category		Technology		Option Parameters									
Stage 1	LEU oxide fuel is irradiated in existing commercial PWRs to approximately the current average discharge burnup (~50 GWd/t). Discharged fuel (DF) is cooled in on-site spent fuel storage and sent to geologic disposal.		(A) Nuclear Fuel Material Supply Systems - Mined Material													
					Mined and Processed Uranium	Option Parameters										
			(B) Nuclear Fuel Enrichment Systems - Enriched Material		Low-Enriched Uranium	Option Parameters										

Figure 1a. Example of the Top Half of the Fuel Cycle Option Summary Description in the Nuclear Fuel Cycle Options Catalog

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	(B) Nuclear Fuel Enrichment Systems - Waste Depleted Uranium (Waste) Option Parameters	
	(C) Fuel Fabrication and Assembly Systems Contact-handled Fabrication Process for Uranium-based Ceramic Fuels Option Parameters	
	(C) Fuel Fabrication and Assembly Systems - Fresh Fuel Pressurized Water Reactor UOX Fuel Option Parameters	
	(D) Transmutation Systems Pressurized Water Reactor (PWR) Option Parameters	
	(D) Transmutation Systems - Waste Pressurized-Water Reactor UOX Spent Fuel (Waste) Option Parameters	
	(H) Nuclear Fuel Storage Systems - Waste Pressurized-Water Reactor UOX Spent Fuel (Waste) Option Parameters	
	(I) Nuclear Fuels Transport Systems - Waste Pressurized-Water Reactor UOX Spent Fuel (Waste) Option Parameters	
Prepared By E.A. Hoffman (ANL) Internally Reviewed By T.K. Kim (ANL) Externally Reviewed By N. Brown, H. Ludewig (BNL) and H. Greenberg (LLNL) Accepted By T.K. Kim (ANL) and E. Hoffman (ANL)	Date Apr 11, 2013 Approval Date Apr 11, 2013 Approval Date Apr 28, 2013 Acceptance Date Apr 30, 2013	
6/27/2013 4:59:33 PM Page 1 of 1 Option Detail, v2.9		
Local intranet Protected Mode: Off		

Figure 2. Example of the Bottom Half of the Fuel Cycle Option Summary Description in the Nuclear Fuel Cycle Option Catalog

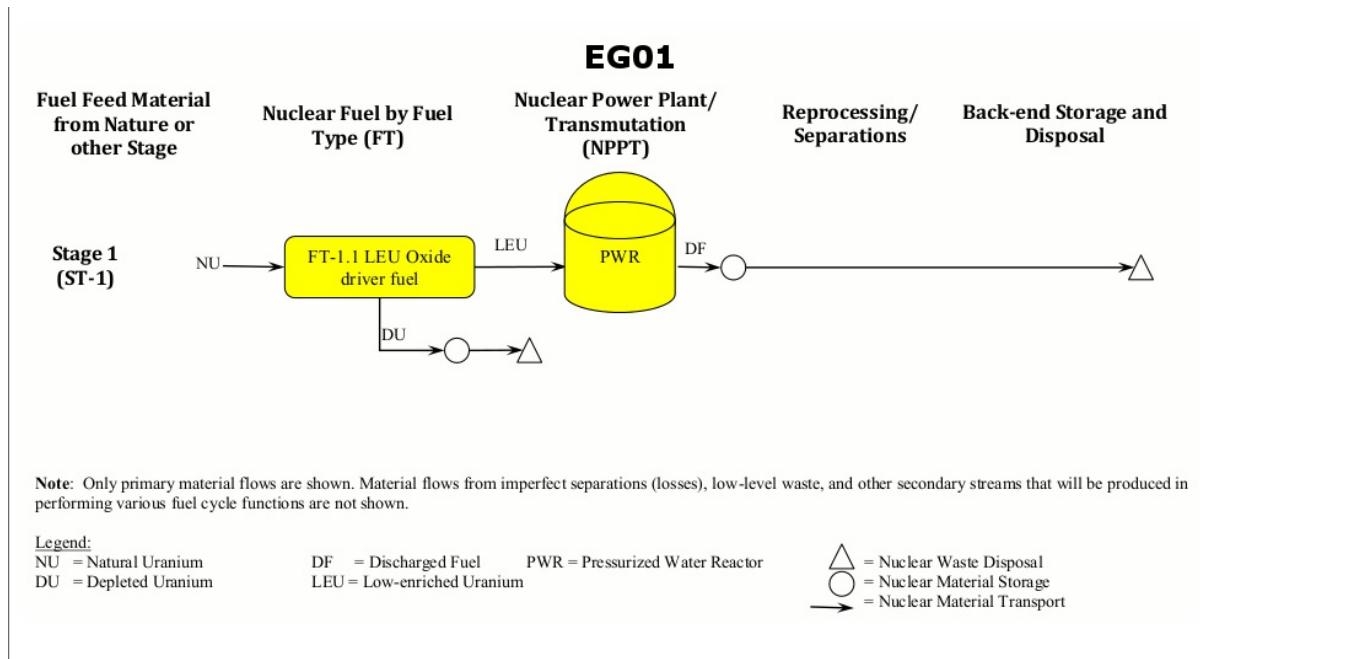


Figure 3. Example of Interactive Flow Diagram in the Nuclear Fuel Cycle Options Catalog

Option Technology Parameters

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PWR LEU Base Case - EG01 (OT01A)

Stage Nbr	Technology Category	(D) Transmutation Systems	Technology	Pressurized Water Reactor (PWR)																														
Technology Description	This is the state of the art commercially deployed Pressurized Water Reactor (PWR). PWR technology is Light-Water Cooled Thermal Reactor (LWR) technology where the pressure/temperature in the primary coolant system is designed to prevent bulk boiling. The primary coolant flows through a steam generator where the nuclear heat is transferred to the secondary side to produce the steam to drive a conventional steam generator. The power level, power density, and other parameters vary substantially depending on the design. The reference size is typically around 1 GWe, but varies from somewhat less than 0.4 GWe to around 1.5 GWe depending on the specific design and desires of the customer.	(D) Transmutation Systems	Technology	Data Pkg EG01/OT01A																														
<p>A wide range of fuel and targets have been designed for utilization in this type of reactor. Most currently operate on LEU oxide fuel with average discharge burnups of approximately 50 MWd/kg. However, there is experience with Pu-MOX fuel. Fuel and targets including Th-based, TRU, LLFPs, extended lifetime fuels, heterogeneous fuel assemblies in a driver and target/blanket type arrangement, and many other variations (for instance, CORAIL, CONFU, etc.) have been considered in varying levels of detail for irradiation in PWRs.</p>																																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #cccccc;">Parameter Name</th> <th style="background-color: #cccccc;">Unit of Measure</th> <th style="background-color: #cccccc;">Value</th> </tr> </thead> <tbody> <tr> <td>Capacity factor</td> <td>%</td> <td>90</td> </tr> <tr> <td>Core Configuration</td> <td>Text</td> <td>PWR with UOX</td> </tr> <tr> <td>Core Thermal Power</td> <td>MWth</td> <td>3000</td> </tr> <tr> <td>Electrical Energy Generation Sharing</td> <td>%</td> <td>100</td> </tr> <tr> <td>Net Thermal Efficiency</td> <td>%</td> <td>33</td> </tr> <tr> <td>NPPT Technology Identifier</td> <td>Text</td> <td>PWR</td> </tr> <tr> <td>Specific Power Density</td> <td>MW/Initial Heavy Metal Metric Ton</td> <td>33.69</td> </tr> <tr> <td>Technology Readiness Level Note: TRL will be evaluated by the Evaluation and Screening Team.</td> <td>Scale from 1 to 9</td> <td>9</td> </tr> <tr> <td>Technology Readiness Level - Brief Justification</td> <td>Text</td> <td>Commercialized</td> </tr> </tbody> </table>					Parameter Name	Unit of Measure	Value	Capacity factor	%	90	Core Configuration	Text	PWR with UOX	Core Thermal Power	MWth	3000	Electrical Energy Generation Sharing	%	100	Net Thermal Efficiency	%	33	NPPT Technology Identifier	Text	PWR	Specific Power Density	MW/Initial Heavy Metal Metric Ton	33.69	Technology Readiness Level Note: TRL will be evaluated by the Evaluation and Screening Team.	Scale from 1 to 9	9	Technology Readiness Level - Brief Justification	Text	Commercialized
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Technology Readiness Level - Brief Justification	Text	Commercialized																																

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Figure 4. Example of Transmutation System Description and Parameter Values in the Nuclear Fuel Cycle Options Catalog

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Option Technology Material Parameters



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PWR LEU Base Case - EG01 (OT01A)

Stage Nbr	1	Technology Category	(C) Fuel Fabrication and Assembly Systems - Fresh Fuel	Technology Material	Pressurized Water Reactor UOX Fuel
Technology Material Description	Oxide fuel is composed of ceramic fuel pellets placed in fuel rods that are combined into fuel assemblies. A fuel pellet is a thimble-sized ceramic cylinder consisting of heavy metal in oxide form. The fuel rods are long, slender, zirconium metal alloy sealed pressure tube with the pellets stacked inside held in place by springs to allow for a large fission gas plenum to accommodate the release of some of the fission gases. The fuel assembly is a structured group of fuel rods, control rod guide tubes, and a central instrument thimble tube held in place by a series of Inconel grids along with hardware above and below the fuel pins to hold the assembly in place, for moving the assembly, coolant flow, etc. Current operation experience allows for average fuel assembly burnups of approximately 5%. Pellets are chamfered on the corners to reduce stress on the fuel rod, manufacture at approximately 95% of theoretical density to accommodate fission gases within the pellet, and smear density of approximately 90%.	Data Pkg	EG01/OT0 1A		
A range of burnups have been considered for future use, from 33 to 100 MWth-day/kg-iHM.[5] The fuel cycle assumption document [3] specifies that the reference is 51 MWth-day/kg-iHM.[4]. The FIMA and initial U235 enrichment, burnup, number of batches, and cycle length must be internally self-consistent. The authors are unaware of any full core analyses at high burnup, e.g., 75 and 100 MWth-day/kg-iHM. With such long cycle lengths the need in burnable poison must be very large and getting a reasonable power distribution must be difficult.					

Parameter Name	Unit of Measure	Value
Average Discharge Burnup	GW-d/t	50
Chemical Form	Text	Oxide
Enrichment Tailing	%	0.25
Fabrication Losses	%	0.2
Fuel Composition: (U-235 + U-233)/Total U	%	4.21
Fuel Composition: Initial Nuclear Materials	Text	LEU
Fuel Composition: Th/Total HM	%	0
Fuel Composition: TRU/Total HM	%	0
Fuel Fabrication Time and Lag Time before use in NPPT	Years	2.0
Fuel Non-fissionable (or Spallation) Target Material	Text	n.a.
Fuel Physical Form	Text	Pin Bundle – Ductless
Fuel Residence Time in Reactor	Effective Full-Power Years	4.1
Fuel Technology Identifier	Text	PWR-UOX
Non-fissionable Target Charge Rate	kg/GWe-yr	n.a.
Non-fissionable Target Transmutation Fraction	%	n.a.
Post Irradiation and Separation (if applicable) Time before Fabrication/Disposal	Years	n.a.
Purpose	Text	Driver
Separation Process(es) Used as Source	Text	n.a.
Technology Readiness Level Note: TRL will be evaluated by the Evaluation Screening Team (EST), but input may be provided on the FCDP.	Scale from 1 to 9	9
Technology Readiness Level - Brief Justification	Text	Commercialized

Figure 5. Example of Fuel Description and Parameter Values in the Nuclear Fuel Cycle Options Catalog



Option Technology Parameters



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[Fuel Cycle Catalog Home Page](#)

SFR Breed and Burn with Fuel Reconditioning - EG09 (SL01)

Stage Nbr	1	Technology Category	(F) Fuel Material Recovery and Separation Systems	Technology	Melt-Refining Process																		
Technology Description	The melt-refining process has been developed for recycling metallic fuel during the Experimental Breeder Reactor II project. The process involves loading the decladched fuel into zirconia crucibles, melting at ~1400°C for several hours under argon atmosphere, and recovering fuel as ingot. Fission products can be divided into three groups, according to their behaviors during the process. The first group is gaseous and volatile fission products (Kr, Xe, I, etc.), which are released as off-gas. The second group is solid fission products (Y, Sr, Te, lanthanides, etc.) reactive with zirconia, which are separated from molten alloy by diffusion into the crucible matrix and adhesion to the crucible surface. The third group is the fission products (Zr, Mo, Tc, etc.) known as "fissium element," which are not separated from the molten alloy because of non-volatile and less reactive properties. Regarding actinides, thorium and americium are separated from the molten alloy because they are chemically reactive with zirconia and a fraction of the other actinides may be left on the crucible surface.			EG09/SL01																			
Data Pkg																							
<table border="1"> <thead> <tr> <th>Parameter Name</th> <th>Unit of Measure</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Potential Reprocessing/Separations Approach</td> <td>Text</td> <td>Melt refining</td> </tr> <tr> <td>Recovery Efficiency & Descriptive Information Note: Recovery Efficiency is the net plant efficiency minus the fraction of material that ends up in recycled material or intended waste stream (e.g. excess recovered uranium)</td> <td>Percent, Text</td> <td>5% or less for Th and Am, 99% for all other actinides, 0.1% or less for Br, Kr, Rb, Cd, I, Xe, Cs, 5% or less for Sr, Y, Te, Ba and lanthanides, 99% for all other FP</td> </tr> <tr> <td>Separation</td> <td>Text</td> <td>U/TRU/FP and FP</td> </tr> <tr> <td>Technology Readiness Level Note: TRL will be evaluated by the Evaluation and Screening Team.</td> <td>Scale from 1 to 9</td> <td>TBD</td> </tr> <tr> <td>Technology Readiness Level - Brief Justification</td> <td>Text</td> <td>TBD</td> </tr> </tbody> </table>						Parameter Name	Unit of Measure	Value	Potential Reprocessing/Separations Approach	Text	Melt refining	Recovery Efficiency & Descriptive Information Note: Recovery Efficiency is the net plant efficiency minus the fraction of material that ends up in recycled material or intended waste stream (e.g. excess recovered uranium)	Percent, Text	5% or less for Th and Am, 99% for all other actinides, 0.1% or less for Br, Kr, Rb, Cd, I, Xe, Cs, 5% or less for Sr, Y, Te, Ba and lanthanides, 99% for all other FP	Separation	Text	U/TRU/FP and FP	Technology Readiness Level Note: TRL will be evaluated by the Evaluation and Screening Team.	Scale from 1 to 9	TBD	Technology Readiness Level - Brief Justification	Text	TBD
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Separation	Text	U/TRU/FP and FP																					
Technology Readiness Level Note: TRL will be evaluated by the Evaluation and Screening Team.	Scale from 1 to 9	TBD																					
Technology Readiness Level - Brief Justification	Text	TBD																					

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Figure 6. Example of Separations Process Description and Parameter Values in the Nuclear Fuel Cycle Options Catalog

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Fuel Cycle Data Package (FCDP)

System Datasheet
PWR LEU Base Case

PWR-UOX

Mass Flow Data										
Stage	1			2			3			Sum ^{b)}
Technology	Fuel	NPPT	Rep/Sep	Fuel	NPPT	Rep/Sep	Fuel	NPPT	Rep/Sec	
Electricity, GWe-yr	100.0									100
Feed or product of nuclear materials (metric ton)^{a)}										
Natural resource	NU	-18,862.8								-18,862.8
	Th									-
Products from fuel or NPPT technology	DU	+16,666.9								+16,666.9
	U	+2,191.5	-2,191.5							0.0
	Pu									
	MA									
	DF		+2,191.5							+2,191.5
Products from Rep/Sep technology	RU									
	Pu									
	MA									
	FP									
Loss		+ 4.4								+ 4.4
References		2								

- a) Mass flow in metric ton was developed to produce 100.0 GWe-year from whole nuclear fleet and the signs (-) and (+) indicate the feed and production to or from each technology category, respectively.
- b) Summation of each row indicates the required resource (-) or produced nuclear materials (+) per year to generate electricity of 100 GWe-yr.

Figure 7. Example of a Mass Flow Data Table in the Nuclear Fuel Cycle Options Catalog



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Fuel Cycle Option References

NOTE: For references that are copyright-protected, only a summary of the document can be opened.

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PWR LEU Base Case - EG01 (OT01A)

Reference Title (click to display where used)	View Document	Report Number	Reference Usage	Authors	Publisher	Publish Location	Publish Date
Assessment of Fuel Cycle Parameters of PWR Once-Through Cycle Option	Open Full Document	N/A	Used to support parameters values for transmutation system, nuclear fuel and mass flow data.	E. A. Hoffman	Argonne National Laboratory	Argonne, IL	April 18, 2013
Assumptions for Nuclear Energy Systems Analyses Rev. 2	Open Full Document	FCRD-FCO-2012-000026	Used to support fuel parameters.	DOE, Fuel Cycle R&D	Prepared for the United States Department of Energy	N/A	December 15, 2012
Core Transmutation Data for Double-Tier Scenario Studies - Scenario 2	Open Full Document	N/A	Used to support parameters values for transmutation system and nuclear fuel.	T.A. Taiwo, E.A. Hoffman, and T.K. Kim	Argonne National Laboratory	Argonne, IL	August 22, 2007

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OptionReferences, v2.4

Figure 8. Example of Reference Database Report in the Nuclear Fuel Cycle Options Catalog

The isotopic composition of the fuel(s) entering and exiting each reactor in each stage is captured and can be accessed by clicking on “Option Isotopic Data File” in the “View Additional Fuel Cycle Option Information” box in the Fuel Cycle Option Detail report (Figure 1). An example of a truncated isotopic composition file is shown in Figure 9. (The file was truncated because it would otherwise be several pages long.)

Isotopic composition for EG#01 (OT01A) generated by Nicolas Stauff
(nsttauff@anl.gov)

isotope	ST1-charged (g)	ST1-discharged (g)
H3	0.000e+00	8.546e-02
HE4	0.000e+00	9.175e-01
LI6	0.000e+00	2.419e-04
LI7	0.000e+00	1.549e-05
BE9	0.000e+00	2.978e-05
BE10	0.000e+00	1.989e-04
C14	0.000e+00	4.018e-05
CO72	0.000e+00	1.179e-12
CO73	0.000e+00	3.658e-13
CO74	0.000e+00	6.607e-14
CO75	0.000e+00	6.588e-15
NI72	0.000e+00	4.478e-10
NI73	0.000e+00	6.146e-11
NI74	0.000e+00	6.027e-11
NI75	0.000e+00	6.817e-12
NI76	0.000e+00	2.629e-12
NI77	0.000e+00	1.749e-13
NI78	0.000e+00	2.759e-14
CU66	0.000e+00	1.149e-13
CU67	0.000e+00	1.210e-16
CU72	0.000e+00	2.199e-09
CU73	0.000e+00	1.889e-09
CU74	0.000e+00	3.598e-10
CU75	0.000e+00	4.759e-10
CU76	0.000e+00	1.019e-10
CU77	0.000e+00	6.338e-11
CU78	0.000e+00	9.353e-12
CU79	0.000e+00	3.548e-12
CU80	0.000e+00	2.319e-13

Figure 9. Example of Truncated Isotopic Composition in the Nuclear Fuel Cycle Options Catalog

Finally, the FCDP from which all the option-specific information in the Nuclear Fuel Cycle Options Catalog was taken is also accessible in the catalog. It can be viewed by clicking on “Option Data Package File” in the “View Additional Fuel Cycle Option Information” box in the Fuel Cycle Option Detail report (Figure 1).

4. VERIFICATION OF FCDP DATA ENTRY

To ensure that the data from the FCDPs was accurately entered into the Nuclear Fuel Cycle Options Catalog, personnel at Savannah River National Laboratory verified that the data in the catalog had been entered correctly into the catalog. The verification procedure that was developed and used in this process is shown in Appendix B. A summary of the verification of all 40 options is shown in Table 2. This table is a database report that gives the name of the fuel cycle option, its review disposition (pending, accepted, or rejected), the name of the person who reviewed it, the date of the review, the review comments and responses, and the last date the entries were modified. As shown in this table, the data associated with all 40 fuel cycle options has been verified, as indicated by the “Accepted” status for every option.

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Table 2. Summary of Verification of 40 Nuclear Fuel Cycle Options

Data Pkg. No.	Fuel Cycle Option Title	Review Disposition	Review Author	Review Date	Review Comments	Last Modified Date
EG01/OT01A	<u>PWR LEU Base Case - EG01 (OT01A)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Reference 2.0. FCDP records Apr. 18, 2013. Catalog records February 28, 2012. Response: Reference dates fixed.	Jun-26-2013
EG02/OT01B	<u>HTGR (graphite-moderated, He-cooled) with LEU fuel - EG02 (OT01B)</u>	Accepted	A.O. Delley (SRNL)	May-21-2013	Internal Reviewers approval date. FCDP records May 6, 2013. Catalog records May 7, 2013. Response: Date fixed.	Jun-26-2013
EG03/OT01C	<u>Once Through Heavy Water Reactor with Natural Uranium - EG03/OT01C</u>	Accepted	Alexcia Delley (SRNL)	Jun-25-2013	Comment#1 - Material Flow Diagram. Feed fuel (NU) doesn't link to a Technology Datasheet. Comment #2 - Nuclear Fuel/Post Irradiation and Separation Time before Fabrication/Disposal. FDCP records 5.0. Catalog records 10.0. Comment #3. References. A) Ref #1. FCDP records 2011. Catalog records 2009. B) Ref. #3. Catalog doesn't record ..."on Advances in Reactor Physics" in the title. Responses to comments: #1 - Feed fuel entering the reactor now links correctly. #2 - Parameter values fixed. #3 - References fixed.	Jun-26-2013
EG04/OT02	<u>Breed and Burn SFR without separation - EG04 (OT02)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Comment #1 - Material Flow Diagram. Feed fuel (NU) doesn't link to a Technology Material Datasheet. Comment #2- Nuclear Fuel/Fuel Technology Identifier. FCDP records SFR-metal high burnup. Catalog records TBD. Comment #3- External Reviewers. Catalog missing reviewer's name- J. Gehin (ORNL). Comment #4- References. A) Ref. #1.FCDP records 2010. Catalog records August 10, 2010. B) Ref. #2. FCDP records April 19, 2013. Catalog records February 28, 2013. Comment responses: #1 - The feed fuel (NU) entering the reactor does link to a Technology Material Data Sheet; the NU entering the fuel fabrication facility	Jun-26-2013

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					does not link to a Technology Material Data sheet because one is not available. #2 - Fixed. #3 - Fixed. #4 - A) No change. The catalog is simply more precise than the FCDP. B) Fixed.	
EG05/OT03	<u>High-Conversion HTGR (graphite-moderated, He-cooled) with LEU and Th fuel - (EG05) OT03</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>Comment #1- Nuclear Fuel/Post Irradiation and Separation (if applicable) Time before Fabrication/Disposal. FDCP records 5.0. Catalog records n.a. Comment #2- References. Ref. #1 in FDCP doesn't record DOE as the author.</p> <p>Response to comments: #1: fixed. #2: No change. DOE is the author; the catalog is giving a more complete and accurate reference.</p> <p>Comment #1 –not fixed.</p> <p>Response (again): #1 fixed (really!)</p>	Jun-26-2013
EG06/OT04	<u>ADS (Th) to DF (EG06/OT04)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>Comment #1 - Nuclear Fuel. Fuel Composition. Total U. FCDP records n.a. Catalog records 0. Comment #2 - References. Catalog Missing Reference #2. Note: In preparation to be published as an ORNL/TM.</p> <p>Responses to comments: #1 - fixed. #2 - The catalog does not have the reference because it does not yet exist. For now, all the catalog can do is record that it will be published.</p>	Jun-26-2013
EG07/OT05	<u>ADS(NU) to DF - EG07 (OT05)</u>	Accepted	Alexcia Delley (SRNL)	Jun-25-2013	<p>References. FCDP Ref #2 not recorded in catalog.</p> <p>Response to comments: Reference #2 has now been provided.</p>	Jun-26-2013
EG08/OT06	<u>Subcritical Thorium Blanket Driven by an ICF Neutron Source - EG08 (OT06)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>Comment #1 - Material Flow Diagram. A) Nuclear Fuel Thorium doesn't link to a technology material datasheet and the Technology Material datasheet doesn't have data. B) Target Deuterium doesn't link to a technology material datasheet. C) Multiplier and coolant Beryllium, Lithium technology material datasheet doesn't have data.</p> <p>Comment #2 - References. A) Ref #1, FCDP records July 2011, Catalog doesn.t record a date. B) Ref #3, FCDP records December 2011, Catalog records November 30, 2011.</p> <p>Comment #3 - TDF is not recorded in Catalog.</p>	Jun-26-2013

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					<p>Responses to comments: Comment #1 - The only fuel that has a technology material datasheet and data is the fuel coming into the reactor. The materials coming into the fuel fabrication "boxes" (i.e., thorium, Deuterium, tritium, and lithium-6) do not have datafiles or data. In addition, no data are available for target, multiplier, or coolant. All available data is now linked to correctly.</p> <p>Comment #2 - A) Missing date added. B) FCDP was incorrect; it has been changed to the correct date.</p> <p>Comment #3 - System datasheet for the option is now linked to.</p>	
EG09/SL01	<u>SFR Breed and Burn with Fuel Reconditioning - EG09 (SL01)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>Comment #1. Blanket fuel and Driver fuel doesn't link to a technology material datasheet. Comment #2. Nuclear Power Plant/Transmutation and Reprocessing/Separations. No data recorded on technology material datasheet. Comment #3. Ref #1. A) FCDP records 2012. Catalog records February 28, 2012. B) FCDP records 1986. Catalog records June 1987.</p> <p>Responses to comments:#1 - Fixed. #2 - Fixed. #3 - A) no change. The catalog has more detailed information. B) Fixed.</p>	Jun-26-2013
EG10/SL02	<u>MSR-Th with limited recycle (EG10/SL02)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>References. Ref # 2 and #4. Catalog does not reference system data sheet(s).</p> <p>Responses to comments: The report by Powers is not used in the FCDP to support anything specifically; the Reference Usage was updated with "Not specified in FCDP." The Rosenthal et al. document is used to support the mass flow data via a footnote to that table; the Reference Usage was updated accordingly.</p>	Jun-26-2013
EG11/SL03	<u>Thorium Breed and Burn with LEU Support in SFR with Partial Separation - EG11 (SL03)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	No Comments	Jun-26-2013

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EG12/ML01	<u>Recover Pu from HWR(NU) and limited recycle in PWR - EG12 (ML01)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>Comment #1 - Reprocessing/Separations. Brief Justification of TRL - text missing from catalog datasheet. Comment #2. Reference #1. FCDP records 2011. Catalog records 2009.</p> <p>Response to comments: #1 - Fixed. #2 - Fixed.</p> <p>Comment #1 - Not Fixed</p>	Jun-26-2013
EG13/ML02	<u>Recover Pu from PWR and limited recycle in PWR (PWR-UOX to PWR-MOX) - (EG13)ML02</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>Revision Number. FCDP records revision 1.1 as the latest revision. The catalog records Rev. 0.0.</p> <p>Response: Revision number has been fixed.</p>	Jun-26-2013
EG14/ML03	<u>Breed Pu in SFR and use it in PWR - EG14 (ML03)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	<p>Comment #1 - Nuclear Fuel. Stage 1.2. Fuel residence time in Reactor. A) FCDP records 9.5. Catalog records 3.9. B) Post Irradiation and Separation time. FCDP records 1.0. Catalog records 5.0. Comment #2 - References. Reference #4. Catalog missing authors and date.</p> <p>Responses to comments: #1 - Fixed. #2 - Fixed.</p>	Jun-26-2013
EG15/ML04	<u>Recover Pu from PWR and Recycle in SFR - EG15(ML04)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	No Comments	Jun-26-2013
EG16 / ML05	<u>Recover Pu from PWR and burn in ADS - EG16 (ML05)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	No Comments	Jun-26-2013
EG17/ML06	<u>Recover Pu from PWR and limited recycle in PWR with Thorium (EG17) ML06</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	<p>Comment #1 - Nomenclature. FCDP records C-T- UTh-Pu-Y. Catalog records Self. Comment #2 - Nuclear Fuel/Physical Form (Stage 2.1). A) FCDP records Pin Bundle- Ductless. Catalog records Oxide. Comment #3 Nuclear Fuel/Separation Process(es) Used as Source (stage 2.1). FCDP records A. Catalog records TBD. Comment #4 - References. Ref. #3. A) FCDP doesn't record the authors B) FCDP records Memo. Catalog records Letter. C) FCDP records March 29, 2013. Catalog records February 22, 2013.</p> <p>Response to Comments: #1: Fixed. #2: Fixed. #3: Fixed. Now says "aqueous," which is what "A" refers to. #4: A) No change. Catalog provides more</p>	Jun-27-2013

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					information. B) Fixed. C) Fixed. Comment #3. Delete "TBD" in catalog.	
EG18/ML07	<u>Recover U3 from PWR and limited recycle in PWR - EG18 (ML07)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Comment #1. Summary Description. Catalog approval dates don't match FCDP dates. Comment #2. Nuclear Power. Catalog records stage 1 data for stage 2. Comment #3. Nuclear Fuel. Catalog records stage 1.1 data for stage 2.1. Response #1: No change made. Dates are input correct. Response #2: Fixed Response #3: Fixed	Jun-26-2013
EG19/SC01	<u>Continuous Pu recycle in HWR - (EG19) SC01</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Nuclear Fuel; TRU/Total HM,%. FCDP records (only Pu). Catalog doesn't record (only Pu) Response to comments: Note added.	Jun-26-2013
EG20/SC02	<u>Continuous TRU recycle in HWR - (EG20) SC02</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Comment #1 - Nuclear Power Plant. Net Thermal Efficiency. Catalog note is not consistent with FCDP note. Comment #2. References. Ref #4. Catalog missing date and publisher. Responses to comments: #1 - Note fixed. #2 - Date and publisher added.	Jun-26-2013
EG21/SC03	<u>Continuous Pu recycle in PWR (CORAIL-Pu) - (EG21) SC03</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Reference 1.0 - September is misspelled.	Jun-26-2013
EG22/SC04	<u>Continuous TRU recycle in PWR (CORAIL-TRU) - (EG22) SC04</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	References. A) Ref .#1 FCDP records Sept. Catalog does not. B) Ref. #2. FCDP records March 12, 2013. Catalog records March 11, 2013. Response: All dates fixed.	Jun-26-2013
EG23/SC05	<u>Continuous Pu Recycle in SFR (Metallic Fuel) - (EG23) SC05</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Comment #1 - Nuclear Fuel/Fuel Composition A) total U% for stage 1.2. FCDP records 0.71. Catalog records ~0.7. B) Initial Nuclear Material for stage 1.2. FCDP records NU. Catalog records U. C) TH/Total HM. FCDP has no entry. Catalog records TBD. Comment #2 - Separations FCDP records U,Pu/RU. Catalog records U,Pu/U. Comment #3 - Reference	Jun-26-2013

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					#1. FCDP records 2009. Catalog records February 5, 2009. Comment #4- Material Flow Diagram. The fuel input (metal) does not link to an Option Technology Material Parameters report. Response to comments: #1: A) fixed, B) fixed, C) put "0" for both stages even though not in the FCDP because this is the correct value. #2: Fixed. #3: No change. Catalog is simply more precise in the date. #4: Added the words "Blanket" and "Driver" to the diagram, and linked these words to the appropriate Option Technology Material Parameters report.	
EG24/SC06	<u>Continuous TRU recycle in SFR (EG24)</u> <u>SC06</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	References. A) Ref #1. FDCP records date as 2006. Catalog records 9/29/05. B) Ref #2. Mass Flow Data System Datasheet records Ref #2. Catalog does not reference the Mass Flow Data System Datasheet. Responses to comments: #1 - Date fixed. #2 - Reference to supporting the mass flow data sheet added.	Jun-26-2013
EG25/SC07	<u>U-233 Recycle in PWR with LEU Support - EG25 (SC07)</u>	Accepted	A. O. Delley	Jun-25-2013	Reprocessing/Separations. Separation. Stage 1.2. Catalog records RU. FCDP records U3.	Jun-26-2013
EG26/SC08	<u>U-233 recycle in MSR - (EG26) SC08</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Nuclear Fuel. Stage 1.1. Physical Form. A) Catalog records noted. FCDP records note a. B) Average Discharge Burn-up. Catalog records note a. FCDP records noted. Response to comments: Notes fixed.	Jun-26-2013
EG27/SC09	<u>U-233 Recycle in SFR with LEU Support - EG27(SC09)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Comment #1. Nuclear Fuel. Catalog does not record data for Stages 1.1 and 1.3, comments #2. Reprocessing /Separations. Separations. Catalog records stage B data for stage A. Comment #3. References. Catalog records Ref #1 where Ref .#2 should be recorded and Ref. #2 where Ref. #1 should be recorded. Response #1: Fixed	Jun-26-2013

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					Response #2: Fixed Response #3: Fixed	
EG28/SC10	<u>Thorium fueled SFR for continuous recycling - (EG28) SC10</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	References. A) Ref#2. FCDP records date as 2006. Catalog records 5/31/2001. B) Ref #3. Catalog does not record author or date. Responses to comments: #1 - Dates now fixed and consistent. #2 - Catalog now records author, date, publisher, and publish location.	Jun-26-2013
EG29/MC01	<u>Breed Pu in SFR and use extra Pu in PWR - EG29 (MC01)</u>	Accepted	A. O. Delley (SRNL)	Jun-25-2013	Comment #1. Nuclear Fuel. Separation Process(es) Used as Source. Stage 2.1. FCDP records B, C. Catalog records C. Comment #2. References. Catalog records Ref #2 for 1st stage reactor, fuel and mass flow. FCDP records for second stages. Responses to comments: #1 - Fixed. #2 - Fixed.	Jun-27-2013
EG30/MC02	<u>Breed TRU in SFR and use extra Pu in PWR - (EG30) MC02</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Comment #1 - Flow Diagram. ST-2. A) The fuel input (TRU/U) doesn't link to an Option Technology Material Parameters report. B) Te Sep-B output stream (Pu/RU) doesn't link to an Option Technology Material Parameters report. Comment #2. Nuclear Power-Stage 2 (PWR) FCDP records reference #2. The catalog records references #1 and #2. Response to comments: #1 - A) and B) both fixed. #2 - Fixed.	Jun-27-2013
EG31/MC03	<u>Burn recovered Pu from PWR in SFR - EG31 (MC03)</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	References. Mass flow Data. Catalog doesn't record Ref. #3 for stage 1. Response: Corrected Reference to support both stages for mass flow data.	Jun-27-2013
EG32/MC04	<u>Burn recovered TRU from PWR in SFR (GNEP scenario) - EG32 (MC04)</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Comment #1. Nuclear Fuel. Stage 2.1. Separation Process(es) Used as Source. FCDP records A, B. Catalog records N/A. Comment #2. References. Ref #3. FCDP records April 24th 2013. Catalog records 2/28/2012). Responses to comments: #1 - Fixed. #2 - Correct date now entered in catalog.	Jun-27-2013
EG33/MC05	<u>Breed Pu in ADS and use extra Pu in PWR -</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Comment #1. Nuclear Fuel. No data in catalog for stages 1.1 and 2.1. Comment #2. References. Ref	Jun-27-2013

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	<u>EG33 (MC05)</u>				#3. Catalog records date as 4/29, 2013. FCDP records data as 4/22/2013. Responses to comments: #1 - Fuel 1.1 now has parameters; Fuel 2.1 now has parameters. #2 - Catalog was correct; FCDP edited to have correct date. Dates now match.	
EG34/MC06	<u>Breed TRU in ADS and use extra TRU in PWR - EG34 (MC06)</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Comment #1. Nuclear Fuel. A) Catalog records stage 1.1 data for stage 2.1. B) Non-fissionable target material. Catalog records N/A for stages 1.1 and 1.2. FCDP records lead/bismuth. C) Physical Form. Stage 2.1. Catalog records oxide. FCDP records Pin Bundle Ductless. Comment #2. Reprocessing/Separations. Stage 1.2. Catalog records the wrong data Response #1: A) Fixed. B) Fixed C) Fixed Response #2: Fixed	Jun-27-2013
EG35/MC07	<u>Burn recovered Pu from PWR in ADS (EG35)</u> <u>MC07</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Summary Description. FCDP records C/S-T/F-U-Pu-Y. Catalog records "self". Response to comments: Fixed.	Jun-27-2013
EG36/MC08	<u>Recycle Pu in PWR and burn MA in ADS - EG36</u> <u>(MC08)</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Comment #1. Summary page. FCDP prepared by and approval dates are not consistent with catalog dates. Comment #2. Nuclear Fuel. Stage 1.1. Average Discharge Burn-up. Catalog is missing note. Responses to comments: #1 - Dates fixed. Note that the catalog can accommodate only one date for a given field; therefore, if there are multiple dates for a single field, only the most recent date is chosen. #2 - Note added.	Jun-27-2013
EG37/MC09	<u>Stages 1 and 3 are PWRs, while stage 2 is SFR. Recycle recovered TRU in stage 2 and burn recovered U3 from stage 2 in stage 3. EG37 (MC09)</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Comment #1. Nuclear Power Plant. Catalog records Stage 1 PWR data as Stage 3 PWR data. Stage 3 catalog and FCDP data do not match. Comment #2. Flow Diagram and Nuclear Fuel. Catalog flow diagram links Stage 3.1 icon to stage 1.1 data. No data recorded in catalog for stage 3.1. Comment #3. Reprocessing/Separations. Separation. A) Stage 2.2 catalog records U, TRU, FP. FCDP records Th, U3, FP. B) Stage 3.1 catalog doesn't record U3. Comment #4. References. Ref#3 catalog records	Jun-27-2013

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					December 1973. FCDP records November 1973. Comment #4. References. Ref#3 catalog records December 1973. FCDP records November 1973.	
					Responses to comments: #1 - Fixed #2 - Fixed #3 - Fixed #4 - FCDP was incorrect and has been fixed.	
EG38/MC10	<u>Recycle U-233 in SFR and PWR - (EG38) MC10</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	Comment #1 - Nomenclature. FCDP records C-T/F-UTh-U3-N. Catalog doesn't record the "U" prior to the Th. Comment #2 - Nuclear Fuel/References (Stage 2.1). FCDP missing ref. #1. Comment #3 - Mass Flow Diagram/ References. FCDP missing reference #1. Response to comments: #1: Fixed. The FCDP has been corrected. #2: No change made. The FCDP is not "missing" reference #1. Reference #1 is not used to support the fuel data in the second stage. #3: No change made. The FCDP is not "missing" reference #1. Reference #1 is not used to support the mass flow data.	Jun-27-2013
EG39/MC11	<u>Recycle recovered U3 from stage 1 in stage 2 (both PWRs), while burn TRU in ADS - EG39 (MC11)</u>	Accepted	A. O. Delley (SRNL)	Jun-26-2013	No Comments	Jun-27-2013
EG40/MC12	<u>Breed U3 in ADS and recycle it in PWR - EG40 (MC12)</u>	Accepted	A. O. Delley	Jun-26-2013	Comment #1. Nuclear Fuel. Stage 1.1. The catalog records "n.a." for ADS Target Material, Target Charge Rate and Transmutation Fraction. The FCDP records data. Comment #2. Summary Description. The Mass Flow Data icon links to the diagram versus the System Datasheet. Responses to comments: #1 - Fixed. #2 - Fixed.	Jun-27-2013

REFERENCES

Kim, T. K.; Hoffman, E. A.; and Taiwo, T. A. Completion of Fuel Cycle Data Package System Datasheets for 2013 Evaluation and Screening, Prepared for the U.S. Department of Energy Fuel Cycle Options Campaign, ANL-FCT-333, FCRD-FCO-2013-000165, May 30, 2013.

Todosow, M.; Taiwo, T.; Kim, T.; Buelt, J.; Jenni, K.; Gehin, J.; Worrall, A.; Halsey, W.; Jubin, R.; Oakley, B.; Ludewig, H.; and Wigeland, R. Comprehensive Fuel Cycle Options List to be Used for the 2013 Evaluation and Screening, Prepared for the U.S. Department of Energy Fuel Cycle Options Campaign, FCRD-FCO-2012-000164, March 29, 2013.

Appendix A

Example of a Fuel Cycle Data Package

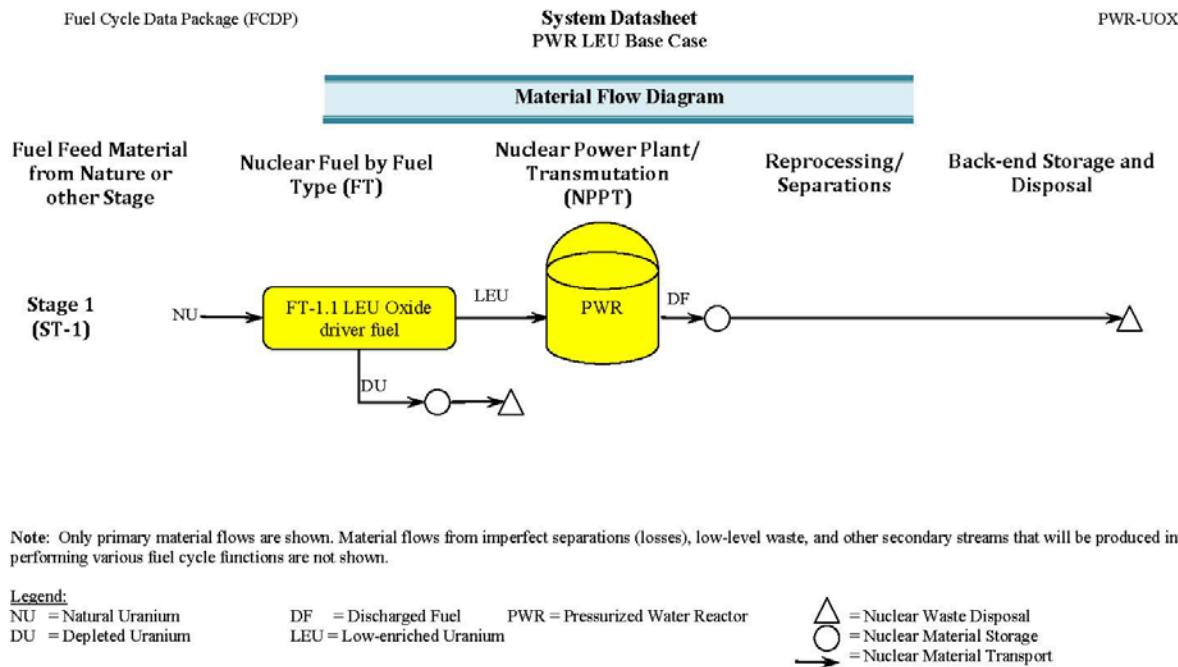
Fuel Cycle Data Package (FCDP)

System Datasheet

PWR-UOX

Summary Description

Fuel Cycle Option No. (Evaluation Group Nomenclature)	EG01/OT01A (C-T-U-Y)	Roadmap Strategy	Once- through	Recycle Strategy	No Recycle				
Fuel Cycle Option Title	PWR LEU Base Case								
Revision number	Revision remarks								
Rev. 0.0	Initial Revision								
Rev. 0.1	Revised due to changes of references and FCDP template version (rev. 0.1)								
Rev. 0.2	Template Revision								
Rev. 1.0	Incorporation of external review comments								
High-level Objective(s)	1) Produce electricity 2) Can utilize existing thermal reactor infrastructure								
No. of Stages	1	Stage Description							
Stage 1 UOX fuel PWR	LEU oxide fuel is irradiated in existing commercial PWRs to approximately the current average discharge burnup (~50 GWd/t). Discharged fuel (DF) is cooled in on-site spent fuel storage and sent to geologic disposal.								
Prepared by	Edward Hoffman (ANL)	Date	Apr. 12, 2013						
Internally Reviewed by	T. K. Kim (ANL)	Approval Date	Apr. 12, 2013						
Externally Reviewed by	N. Brown, H. Ludewig (BNL) H. Greenberg (LLNL)	Approval Date	Apr. 12, 2013						
			Apr. 29, 2013						
Accepted by	T. K. Kim (ANL) E. Hoffman (ANL)	Acceptance Date	May 1, 2013						



Fuel Cycle Data Package (FCDP)

System Datasheet
 PWR LEU Base Case

PWR-UOX

High Level Parameter Data

Technology category	Parameter	Stage Number			
		1	2	3	4
Nuclear Power Plant/ Transmutation (NPPT)	NPPT Technology Identifier	PWR			
	Core Configuration	PWR with UOX			
	Core Thermal Power, MWth	3000			
	Net Thermal Efficiency, %	33			
	Capacity Factor, %	90			
	Specific Power Density, MW/IHMMT*	33.69			
	Technology Readiness Level (TRL)	9			
	Brief Justification of TRL:	Commercialized			
	Electrical Energy Generation Sharing, %	100.0			
	Reference(s)	1, 2			

* IHMMT: Initial Heavy Metal Metric Ton.

Fuel Cycle Data Package (FCDP)

System Datasheet
PWR LEU Base Case

PWR-UOX

Technology category	Parameter	Fuel Type Number (1 st digit denotes Stage No.)				
		1.1				
Nuclear Fuel	Fuel Technology Identifier	PWR-UOX				
	Purpose	Driver				
	Chemical Form	Oxide				
	Physical Form	Pin Bundle – Ductless				
	Average Discharge Burnup, GWd/t	50				
	Fuel Composition	Initial Nuclear Material(s)	LEU			
		(U-235+ U-233)/Total U, %	4.21			
		Th/Total HM, %	0			
	TRU/Total HM, %	0				
	Non-fissionable Target materials	n.a.				
	Non-fissionable Target Charge Rate, kg/GWe-yr	n.a.				
	Non-fissionable Target Transmutation Fraction, %	n.a.				
	Fabrication Losses, %	0.2				
	Separation Process(es) Used as Source	n.a.				
	Enrichment Tailing, %	0.25				
	Fuel Fabrication Time and Lag before Use in NPPT, years	2.0				
	Fuel Residence Time in Reactor, EFPY	4.1				
	Post Irradiation and Separation (if applicable) Time before Fabrication/Disposal, years	n.a				
	Technology Readiness Level (TRL)	9				
	Brief Justification of TRL:	Commercialized				
	Reference(s)	1, 2, 3				

Note: Repeat table if additional columns are required for additional fuel types.

Fuel Cycle Data Package (FCDP)

System Datasheet
PWR LEU Base Case

PWR-UOX

Technology category	Parameter	Reprocessing/Separation Processes				
Reprocessing/Separations	Potential Reprocessing/Separations Approach					
	Separation					
	Fuel Type Used as Source					
	Recovery Efficiency (%) & Descriptive Information [†]					
	Technology Readiness Level (TRL)					
	Brief Justification of TRL:					
	Reference(s)					

Note: 1) Additional information included in the Material Flow Diagram.

2) Repeat table if additional columns are required for separation of additional fuel types.

Fuel Cycle Data Package (FCDP)

System Datasheet
PWR LEU Base Case

PWR-UOX

Fuel Cycle Performance Summary – Evaluation Criteria and Metrics

This sheet currently not used. The qualitative information needed to support the fuel cycle evaluation and screening will be evaluated by the Evaluation and Screening Team (EST), while the quantitative metrics that can be calculated using the information in FCDPs will be provided through separate reports.

Fuel Cycle Data Package (FCDP)

System Datasheet
PWR LEU Base Case

PWR-UOX

Mass Flow Data

a) Mass flow in metric ton was developed to produce 100.0 GWe-year from whole nuclear fleet and the signs (-) and (+) indicate the feed and production to or from each technology category, respectively.

b) Summation of each row indicates the required resource (-) or produced nuclear materials (+) per year to generate electricity of 100 GWe-yr.

Fuel Cycle Data Package (FCDP)

System Datasheet
PWR LEU Base Case

PWR-UOX

Transition and Scenario Analysis Data
(Provide references, if any, and brief description)

This sheet is currently optional, but the user can provide any available transition or scenario fuel cycle information.

Fuel Cycle Data Package (FCDP)

System Datasheet
PWR LEU Base Case

PWR-UOX

References

Reference	Distribution Restrictions
1. T. A. Taiwo, E. A. Hoffman, and T. K. Kim, <i>Core Transmutation Data for Double-Tier Scenario Studies –Scenario 2</i> , Intra-laboratory Memo, Argonne National Laboratory, Aug. 22, 2007.	None
2. E. A. Hoffman, “Assessment of Fuel Cycle Parameters of PWR Once-Through Cycle Option,” Intra-Laboratory Memo, Argonne National Laboratory, Apr. 18, 2013.	None
3. Assumptions for Fuel Cycle Analysis	

Note: If possible, reference with distribution limitations should be avoided.

Appendix B

Catalog Content Verification Procedure

Procedure for Verifying Fuel Cycle Option Data in the Fuel Cycle Options Catalog

The purpose of this procedure is to provide written instructions for verifying that the data in a Fuel Cycle Data Package (FCDP) have been correctly entered into the Fuel Cycle Options Catalog. FCDPs are first prepared, reviewed by two reviewers, and then approved. Once a FCDP has been approved, the data in it are entered into the Fuel Cycle Options Catalog. After the data have been entered, a third party that is independent of both FCDP preparation and data entry verifies that the data in the catalog for a given fuel cycle option match the data in the associated FCDP for the fuel cycle option. Specific instructions for performing this verification are given below.

1. **Display list of options to be verified.** From the Nuclear Fuel Cycle Option Catalog home page, click on “Options” at the top of the page.

Nuclear Fuel Cycle Option Catalog

U.S. DEPARTMENT OF ENERGY
Office of Nuclear Energy

Home Options Technologies Materials Screenings FAQ Glossary November 26, 2012

Search this site...

Quick Links

[Options](#)

[Quantitative Metrics](#)

[Qualitative Metrics](#)

[Technologies](#)

[Materials](#)

[Screenings](#)

[FAQ](#)

2. **Select option to be verified.** Select the option for which data are to be verified by clicking on its name.

Nuclear Fuel Cycle Option Catalog > Report Source > ReportSource

Actions ▾ 🔍 ⏪ ⏴ 1 of 1 ⏵ ⏩ 🔍 Find Next 100% 🔍

Fuel Cycle Option Search Summary

U.S. DEPARTMENT OF ENERGY Office of Nuclear Energy Sandia National Laboratories

[Go to Material Summary Page](#) [Go to Technology Summary Page](#) [Return to Fuel Cycle Catalog Home](#)

Fuel Cycle Option Title	Data Pkg	Nbr of Stages	High Level Objectives	Recycle Strategy	Road Map Strategy
Breed and Burn with fuel reconditioning (FCO12)	FCO12	1	High-level Objective(s) 1) Produce electricity and/or process heat 2) Minimize waste disposal by partitioning and/or transmuting isotopes	Limited Recycle	Modified Open
Commercial PWR-UOX Once Through (FCO02)	FCO02	1	Produce electricity and/or process heat.	No Recycle	Once Through
Commercial PWR-UOX Once Through (FCO01)	FCO01	1	1) Produce electricity and/or process heat 2) Capitalize on existing infrastructure	No Recycle	Once Through
Heavy Water Reactor (Once-Through) with Natural Uranium (FCO04)	FCO04	1	1) Produce Electricity 2) Use natural uranium as fuel	No Recycle	Once Through
HTGR TRISO-LEU (without recycle) (FCO03)	FCO03	1	1) Produce electricity and/or process heat 2) Reduce quantity of plutonium (or strategic SNM) generated per unit energy 3) Provide or enhance ability to use natural resources	No Recycle	Once Through
PWR LEU/Th (seed and blanket (FCO05)	FCO05	1	1) Provide or enhance ability to use natural resources 2) Produce electricity and/or process heat 3) Reduce quantity of plutonium (or strategic SNM) generated per unit energy	No Recycle	Once Through

3. **Maximize view.** Maximize the left-hand side of the screen by clicking on the triangle in the vertical gray bar.

Nuclear Fuel Cycle Option Catalog > Report Source > ReportSource

Actions ▾ 🔍 ⏪ ⏴ 1 of 1 ⏵ ⏩ 🔍 Find Next 100% 🔍

Fuel Cycle Option Detail

U.S. DEPARTMENT OF ENERGY Office of Nuclear Energy

[Option Summary Page](#)

Title: Commercial PWR-UOX Once Through (FCO01) **Data Pkg:** FCO01 **Source:**

High Level Objectives: 1) Produce electricity and/or process heat
2) Capitalize on existing infrastructure **Number of Stages:** 1 **Recycle Strategy:**

Parameters
Select a Fuel Cycle Option Title
Commercial PWR-UOX Once Through (FCO01)

View Additional Fuel Cycle Option Information

Interactive Option Flow Diagram	Option Mass Flow Data File	Option References	Option Metrics	Revision Remarks	Convert to
Option Data Package File	Option Isotopic Data File	Option Predecessor/Successors			

Stage Nbr **Stage Description** **Technology Category**

Stage 1 LEU oxide fuel is irradiated in existing commercial PWRs to approximately the current average discharge burnup (~50 GWd/t). Discharged fuel (DF) is cooled in on-site spent fuel storage and sent to geologic disposal.

(A) Nuclear Fuel Material Supply

4. **Verify first page of System Datasheet.** The Fuel Cycle Option Detail report is being viewed. This report represents the starting point for verifying the data in the FCDP for a given option. All the data on the first page of the FCDP, the Summary Description, can be verified from the Fuel Cycle Option Detail report. Namely, the following data can be verified from this report:

- Fuel Cycle Option Number (called Data Pkg in catalog)
- Roadmap Strategy
- Recycle Strategy
- Fuel Cycle Option Title
- Revision Number
- Revision Remarks
- High-level Objectives
- Number of Stages
- Stage Number and Stage Description
- Name of Preparer and Date of Preparation
- Internal Reviewer and Internal Review Date
- External Reviewer and External Review Date
- Acceptance Signature and Acceptance Date

Note that the “Stage Description” information for each stage includes only the text in the “Stage Description” column shown on the system datasheet. If a fuel type and/or separation system appears in the left-hand column under the stage number, these are shown in the table of technologies on the Fuel Cycle Option Detail report, although the names might be slightly different.

5. **Verify second through fifth pages of System Datasheet.** From the Fuel Cycle Option Detail report, the Material Flow Diagram (second page of the FCDP) can be seen and verified by clicking on “Interactive Option Flow Diagram.” First, verify that the correct Material Flow Diagram (page two of the system datasheet) is displayed. In addition, every link on the Interactive Option Flow Diagram must be verified, as described below.

The screenshot shows the 'Fuel Cycle Option Detail' page for option FCO01. Key information includes:

- Title:** Commercial PWR-UOX Once Through (FCO01)
- Data Pkg:** FCO01
- Source:** DOE
- Screening Disposition:** Not Yet Screened
- High Level Objectives:** 1) Produce electricity and/or process heat, 2) Capitalize on existing infrastructure
- Number of Stages:** 1
- Recycle Strategy:** Recycle
- No Recycle:** No Recycle
- Road Map Strategy:** Road Map
- Once Through:** Once Through

In the 'View Additional Fuel Cycle Option Information' section, the 'Interactive Option Flow Diagram' link is highlighted with a red circle.

The first item to be verified is that the correct fuels have been linked to in the Interactive Option Flow Diagram. To do this, click on each fuel that is shown as entering each reactor in each stage and an Option Technology Material Parameters report will appear. Confirm that the technology description and option-specific parameters appearing in the Option Technology Material Parameters Report are correct. The option-specific parameters are shown on page 3 of the Fuel Cycle Data Package. Return to the Interactive Option Flow Diagram by closing the Option Technology Material Parameters report.

Next, verify that the correct reactors have been linked to in the Interactive Option Flow Diagram. To do this, click on the reactor shown in each stage and an Option Technology Parameters report will appear. Confirm that the technology description and option-specific parameters appearing in the Option Technology Parameters report are correct. The option-specific parameters are shown on page 4 of the Fuel Cycle Data Package. Return to the Interactive Option Flow Diagram by closing the Option Technology Parameters report.

Next, verify that the correct separations systems (if included in the option) have been linked to in the Interactive Option Flow Diagram. To do this, click on the separation system shown in each stage and an Option Technology Parameters report will appear. Confirm that the technology description and option-specific-parameters appearing in the Option Technology Parameters report are correct. The option-specific parameters are shown on page 5 of the Fuel Cycle Data Package.

The parameter “Fuel Type Used as Source” in the FCDP is not given in the option parameter table as it is not a parameter. The value of “Fuel Type Used as Source” (e.g., 1.1) was used by the FCDP preparers to identify the type of fuel that is being reprocessed. So, for example, if Fuel Type 1.1 is shown in the Reprocessing/Separation Processes Parameter table on the FCDP (page 5), this indicates that Fuel Type 1.1 as shown on the Fuel Type Number table of the FCDP (page 4) is the fuel that is being

reprocessed. In the catalog, rather than use a number to show which fuel(s) is(are) being reprocessed, the interactive flow diagram is used to show which fuel(s) is(are) being reprocessed. References will be verified at a later step.

Return to the Interactive Option Flow Diagram by closing the Option Technology Parameters report.

Finally, verify that other items on the Interactive Option Flow Diagram (e.g., DU, DF) are described correctly. Clicking on another item will open a Technology Material Detail report that has only a minimal, high-level description of that item. The descriptions of these other items are not based on technology datafiles so no parameters or references are available; thus, no parameters or references need to be verified. However, it should be verified that these other items are described correctly.

Once the material flow diagram and the embedded links have been verified, close the window that the material flow diagram appears in.

6. **Verify sixth page of System Datasheet.** The Fuel Cycle Performance Summary sheet (sixth page of the FCDP) is not used and currently no metrics are stored in the catalog. Hence, nothing on this page requires verification.
7. **Verify seventh page of the System Datasheet.** The Mass Flow Data (seventh page of the FCDP) can be verified by clicking on “Option Mass Flow Data File.” This will produce a table of mass flow data for the option. Verify that the mass flow data table in the catalog is the same as that which is in the FCDP.

Actions		Find Next	100%								
 U.S. DEPARTMENT OF ENERGY Office of Nuclear Energy											
Fuel Cycle Option Detail											
Option Summary Page											
Title	Commercial PWR-UOX Once Through (FCO01)			Data Pkg FCO01							
High Level Objectives:	1) Produce electricity and/or process heat 2) Capitalize on existing infrastructure	Number of Stages	1	Recycl Strate							
<p style="text-align: center;">View Additional Fuel Cycle Option Information</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 25%; padding: 5px; text-align: center;"> Interactive Option Flow Diagram </td> <td style="width: 25%; padding: 5px; text-align: center;"> Option Mass Flow Data File </td> <td style="width: 25%; padding: 5px; text-align: center;"> Option References </td> <td style="width: 25%; padding: 5px; text-align: center;"> Option Metrics </td> </tr> <tr> <td style="width: 25%; padding: 5px; text-align: center;"> Option Data Package File </td> <td style="width: 25%; padding: 5px; text-align: center;"> Option Isotopic Data File </td> <td style="width: 25%; padding: 5px; text-align: center;"> Option Predecessor/Successors </td> <td style="width: 25%; padding: 5px;"></td> </tr> </table>				Interactive Option Flow Diagram	Option Mass Flow Data File	Option References	Option Metrics	Option Data Package File	Option Isotopic Data File	Option Predecessor/Successors	
Interactive Option Flow Diagram	Option Mass Flow Data File	Option References	Option Metrics								
Option Data Package File	Option Isotopic Data File	Option Predecessor/Successors									
Stage Nbr	Stage Description			Technology Category							
Stage 1	LEU oxide fuel is irradiated in existing commercial PWRs to approximately the current average discharge burnup (~50 GWd/t). Discharged fuel (DF) is cooled in on-site spent fuel storage and sent to geologic disposal.			(A) Nuclear Fuel Material Supply							

8. **Verify eighth page of the System Datasheet.** The eighth page of the system datasheet - Transition and Scenario Analysis Data – is currently not used and is not in the catalog. This page does not require verification.
 9. **Verify ninth page of the System Datasheet.** The references (ninth page of the FCDP) can be verified by clicking on “Option References.” This will produce a report of the

references cited in the option.

Nuclear Fuel Cycle Option Catalog > Report Source > ReportSource

The screenshot shows a web-based application for managing nuclear fuel cycle options. At the top, there's a navigation bar with 'Actions', a search bar, and a zoom level of '100%'. Below the header, the U.S. Department of Energy logo is displayed, followed by the text 'FUEL CYCLE OPTION DETAIL' and 'Option Summary Page'. The main content area has a yellow background. It displays the title 'Commercial PWR-UOX Once Through (FCO01)' and a 'Data Pkg' identifier 'FCO01'. Underneath, there's a section for 'High Level Objectives' which lists '1) Produce electricity and/or process heat' and '2) Capitalize on existing infrastructure'. To the right, 'Number of Stages' is shown as '1'. A large button labeled 'View Additional Fuel Cycle Option Information' contains several links: 'Interactive Option Flow Diagram', 'Option Mass Flow Data File', 'Option References' (which is circled in red), 'Option Metrics', 'Option Data Package File', 'Option Isotopic Data File', and 'Option Predecessor/Successors'. Below this, a table titled 'Stage Description' shows a single row for 'Stage Nbr' 'Stage 1' with a detailed description of the fuel cycle process. The bottom right corner of the main content area has the text '(A) Nuclear Fuel Material'.

Stage Nbr	Stage Description	Technology Ca
Stage 1	LEU oxide fuel is irradiated in existing commercial PWRs to approximately the current average discharge burnup (~50 GWd/t). Discharged fuel (DF) is cooled in on-site spent fuel storage and sent to geologic disposal.	

10. **Verify Reference Usage.** The Fuel Cycle Option References report documents how each reference was used in the FCDP. That is, the “Reference Usage” column indicates which parameters are supported by each reference. This can be verified against the FCDP by looking at each reference in the FCDP and finding where it is listed as a reference in the pages of the FCDP. For example, if reference 1 in the FCDP is cited as a reference for the first stage transmutation system (page 3 in the FCDP) and the first stage fuel (page 4 of the FCDP), then the “Reference Usage” column in the catalog should state that the reference is used to support the parameters for the first stage transmutation system and the first stage fuel. Once the reference usage for each

reference is verified, return to the Fuel Cycle Option Detail report by clicking on “Return to Option Detail.”

Nuclear Fuel Cycle Option Catalog > Report Source > ReportSource

Actions ▾ 🔍 ⏪ 1 of 3 ⏩ Find Next 100% 🔍

Fuel Cycle Option References

Commercial PWR-UOX Once Through (FCO01)

[Return to Fuel Cycle Option Detail](#) [Return to Fuel Cycle Catalog Home](#)

NOTE: For references that are copyright-protected, only a summary of the document can be opened.

Reference Title (click to display where used)	View Document	Report Number	Reference Usage	Authors	Publisher	Publish Location	Publish Date
Assessment of Fuel Cycle Parameters of PWR Once-Through Cycle Option	Open Full Document	N/A	Used to support parameters for first stage transmutation system and first stage fuel.	E. A. Hoffman	Argonne National Laboratory	Argonne, IL	February 28, 2012
Core Transmutation Data for Double-Tier Scenario Studies - Scenario 2	Open Full Document	N/A	Used to support parameters for first stage transmutation system and fuel.	T.A. Taiwo, E.A. Hoffman, and T.K. Kim	Argonne National Laboratory	Argonne, IL	August 22, 2007

11. Return to Catalog Home Page. Once all data in a FCDP has been verified, return to the Home page of the catalog. This can be done in several ways; one way is to click on “Fuel Cycle Catalog Home Page.”

Nuclear Fuel Cycle Option Catalog > Report Source > ReportSource

Actions ▾ 🔍 ⏪ 1 of 1 ⏩ Find Next 100% 🔍

Fuel Cycle Option Detail

[Option Summary Page](#) [Fuel Cycle Catalog Home Page](#)

Title	Data Pkg	Source	DOE	Screening Disposition	Not Yet Screened
Commercial PWR-UOX Once Through (FCO01)	FCO01				
High Level Objectives:	1) Produce electricity and/or process heat 2) Capitalize on existing infrastructure	Number of Stages	1	Recycle Strategy	No Recycle
		Road Map Strategy		Once Through	

12. Document verification of option. Once on the home page, click on “Option Verification” under Quick Links on the right hand side of the screen. This should open a list of Fuel Cycle Options. Click on the option that was just verified, and a box will appear in which the verification of the option can be entered.

Data Package Fuel Cycle Option Number	FCO01
Data Package Revision Number	Rev 1.0
Data Package Revision Remarks	Convert to new template & add mass flow table
Data Package Completed By	E.A. Hoffman (ANL)
Data Package Completion Date	02/28/2012 mm/dd/yyyy
Data Package External Review By	
Data Package External Review Date	
Data Package Internal Review By	T.K. Kim (ANL)
Data Package Internal Review Date	02/28/2012 mm/dd/yyyy
Data Package Accepted By	
Data Package Accepted Date	
Status	Active ▾
Review Disposition	Pending ▾
Review Comments	
Review Author	
Review Date	09/02/2011 mm/dd/yyyy

OK **Cancel**

Change “Review Disposition” to “Accepted” from the drop-down menu, enter any comments in the “Review Comments” box, enter your name in the “Review Author” box, and the date of the review in the “Review Date” box. Please do not change any other values in this dialog box. Click “OK” when these four entries have been made. The option is now verified.

13. **What to do if something can't be verified.** If, during the procedure outlined above, something cannot be verified because it is incorrect, or it is TBD but should have a value, etc, enter the item(s) that cannot be verified into the Review Comments box in the previous step and DO NOT change “Review Disposition” to “Accepted.” Then please email Laura Price at llprice@sandia.gov with the name of the option that can't be verified. This can be done at any time during the verification procedure, not just at the

end. Do not change “Review Disposition” to “Accepted” until all issues are resolved and everything can be verified.